Standardization of Roadside Counts of Columbids in Puerto Rico and on Vieques Island

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By Frank F. Rivera-Milán

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Standardization of Roadside Counts of Columbids in Puerto Rico and on Vieques Island

by

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Abstract. Ten native species of pigeons and doves (Columbidae) occur in Puerto Rico and its offshore territories: scaly-naped pigeon (*Columba squamosa*), white-crowned pigeon (*C. leucocephala*), plain pigeon (*C. inornata*), white-winged dove (*Zenaida asiatica*), zenaida dove (*Z. aurita*), mourning dove (*Z. macroura*), common ground-dove (*Columbina passerina*), ruddy quail-dove (*Geotrygon montana*), Key West quail-dove (*G. chrysia*), and bridled quail-dove (*G. mystacea*). Roadside counts of the columbids began in 1985 on the Puerto Rican mainland and in 1991 on Vieques Island. Coefficients of variance (CV) in spring were relatively lower than CVs in winter, summer, and fall. Sample-size estimates of the columbids from the roadside counts varied by species, spatial and temporal scales, sensitivity (power of a test of a hypothesis), and precision (width of a confidence interval). For example, at an α of 0.05 (z = 1.96) and a mean CV of 116% (May 1987–92), 538 sampling units (8-km routes) were required for confidence limits of ±10% for the mean number of calling zenaida doves per km in the dry zone of the Puerto Rican mainland. Guidelines for the standardization of roadside counts in Puerto Rico and on other Caribbean islands are given.

Key words: Columbidae, roadside counts, variability, sample-size estimates, spatio-temporal scales, Puerto Rico, Vieques Island.

Ten species of pigeons and doves (Columbidae) are native to Puerto Rico and its offshore territories: scaly-naped pigeon (*Columba squamosa*), white-crowned pigeon (*C. leucocephala*), plain pigeon (*C. inornata*), white-winged dove (*Zenaida asiatica*), zenaida dove (*Z. aurita*), mourning dove (*Z. macroura*), common ground-dove (*Columbina passerina*), ruddy quail-dove (*Geotrygon montana*), Key West quail-dove (*G. chrysia*), and bridled quail-dove (*G. mystacea*; Biaggi 1970; Raffaele 1989; Fig. 1). Four species are legally hunted from September to November: scaly-naped pigeon, white-winged dove, zenaida dove, and mourning dove (Rivera-Milán et al. 1990; Ramos et al. 1991). The white-crowned pigeon is considered threatened, and the plain pigeon, endangered (Pérez-Rivera and Collazo-Algarín 1976; Wiley and Wiley 1979). Whereas the ruddy quail-dove and Key West quail-dove are fairly common in certain localities such as the haystack hills of northwest Puerto Rico, the bridled quail-dove is rare and local in eastern Puerto Rico and on the Vieques and Culebra islands (personal observation). Biaggi (1970), Lack (1976), Bond (1983), Goodwin (1983), Stockton de Dod

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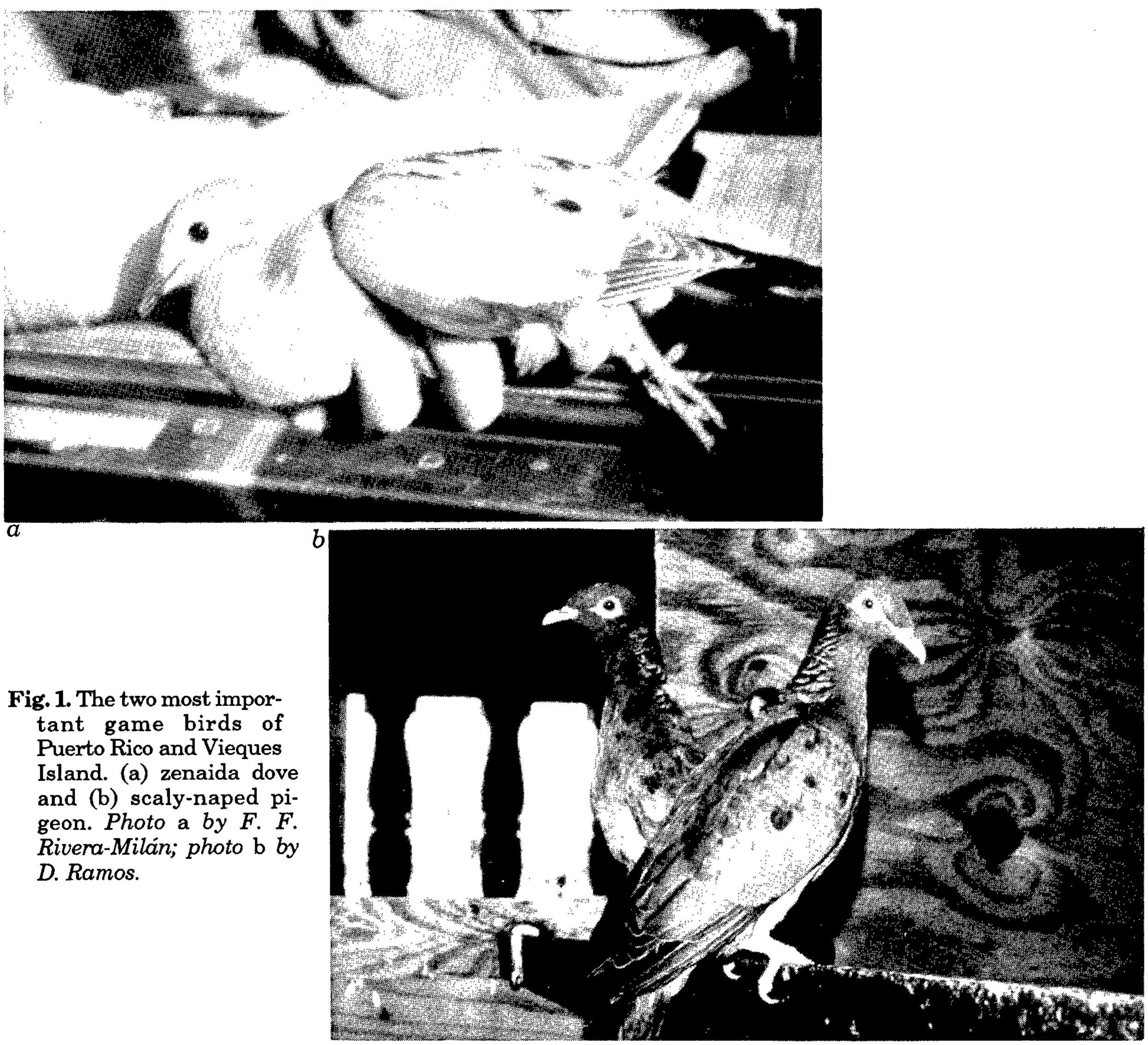
(1987), and Raffaele (1989) presented general information about columbids in the Caribbean region.

In Puerto Rico and on other Caribbean islands, habitat loss and illegal hunting are the two main causes of endangerment of columbid populations (Pérez-Rivera and Collazo-Algarín 1976; Blankinship 1977; Dammann 1977; Murray 1977; Arendt et al. 1979; Wiley and Wiley 1979; Godínez and Fuentes 1987; Godínez et al. 1987; Blockstein 1988; Bancroft et al. 1990; Rivera-Milán 1990a, 1992; Rivera-Milán et al. 1990; Godínez 1993; Rodríguez and Sánchez 1993). Many terrestrial and aquatic bird species are directly or indirectly affected by the same threats (Raffaele 1989). Therefore, long-term studies (≥10 years) are needed to examine population changes over time and provide information for monitoring and managing populations at local and regional scales.

Roadside counts traditionally have been used in the assessment of columbid population trends over large portions of land (Foote et al. 1958; Dolton 1991). In July 1985, roadside counts were initiated to determine the distribution and relative abundance of zenaida doves and scaly-naped pigeons in the three major life zones on the Puerto Rican mainland (Collazo et al. 1985). The scope of roadside counts was expanded to include all ten native species from July 1986 to January 1989 (Rivera-



a *b*

Fig. 1. The two most important game birds of Puerto Rico and Vieques Island. (a) zenaida dove and (b) scaly-naped pigeon. *Photo* a *by F. F. Rivera-Milán; photo* b *by D. Ramos.*

Milán 1990a, 1992). Since May 1989, roadside counts have been conducted annually from the second week of May to the second week of June to cover the reproductive peak of the columbids (Rivera-Milán 1990a; Rivera-Milán et al. 1990; Ramos et al. 1991). Vieques Island was included in the sampling scheme of roadside counts in May 1991 to examine the status, distribution, and relative abundance of the columbids after Hurricane Hugo (Rivera-Milán 1990b, unpublished data).

Eberhardt (1978) used data on terrestrial species in the literature to calculate coefficients of variance (CVs) of relative-abundance indices and noted that they were rather high but sufficiently constant within taxa to provide approximate guides for population studies. For example, CVs of call counts of mourning doves were in the order of 60–70%; and CVs of sight counts were in the order of 90–100% (Foote et al. 1958, as cited by Eberhardt 1978: Table 7). However, the mourning dove is one of the most widely distributed and abundant avian species in North America (Robbins et al. 1986; Tomlinson et al. 1988). Roadside counts of uncommon and local species (e.g., white-crowned pigeons, plain pigeons, and bridled quail-doves) may have higher CVs than those of common and widely distributed species (e.g., common ground-doves, zenaida doves, and scaly-naped pigeons). Hence, the distribution and abundance of uncommon species might result in highly variable roadside counts not suitable to reliably monitor population trends. An estimation of the variability of roadside counts during the reproductive peak of the columbids facilitates the assessment of the reliability of population changes over specific spatial and temporal scales (Rivera-Milán 1990a, 1992, unpublished data). But multiple counts per year may be necessary for a desired level of precision of a population-size trend estimate from highly variable count data (Gates et al. 1975; Eberhardt 1978; Gates 1981; Harris 1986). For certain species, only a combination of counting techniques (e.g., roost, nest, and roadside counts) may yield the necessary information for studying population trends efficiently (Eberhardt 1978).

My approach to the problem of conducting standardized roadside counts can be considered as exploratory because I emphasize the most basic statistical properties of the most general patterns of distribution and relative abundance of the columbids (James and McCulloch 1985; Rivera-Milán 1992). I had three specific objectives: (1) to examine descriptive statistics of roadside counts at different spatial (routes, life zones, island-wide) and temporal (months, seasons, years) scales; (2) to obtain direct estimates of the variability of counts and determine the number of within-year sampling units (routes) needed per life zone for confidence limits of ±10–50% for the mean number of aural and visual detections per km during the May–June counting period; and (3) to offer guidelines for the standardization of roadside counts in Puerto Rico and on other Caribbean islands where the status, distribution, and relative abundance of the columbids are presently unknown.

Study Areas and Methods

Puerto Rico and Vieques Island

Puerto Rico is the smallest (8,903 km^2) and easternmost (17° 55′–18° 35′ north, 65° 37′–67° 17′ west) of the Greater Antilles. Vieques Island is the largest offshore territory (162 km^2) and lies 9.7 km east of the Puerto Rican mainland (18° 01′–18° 09′ north, 65° 16′–65° 27′ west; Fig. 2). Ewel and Whitmore (1973) classified the three major life zones of Puerto Rico as a subtropical moist zone (5,326 km^2 of which 1,224 km^2 [ca. 23%] are forested), a subtropical wet zone (2,124 km^2 of which 1,037 km^2 [ca. 49%] are forested), and a subtropical dry zone (1,216 km^2 of which 405 km^2 [ca. 33%] are forested; Birdsey and Weaver 1982). The three major life zones collectively cover approximately 98% of the total land area (Ewel and Whitmore 1973). According to Koenig (1953), the forest of Puerto Rico was reduced to about 6% in the late 1940's mainly through agricultural activities. Birdsey and Weaver (1982) estimated that the forest of Puerto Rico covered about 2,790 km^2 (ca. 32%) in the late 1970's. The forest of Puerto Rico increased to about 3,399 km^2 (ca. 38%) in the late 1980's (Ortiz 1989). Presently, the forest of Puerto Rico is dominated by secondary growth at different stages of recovery. For example, the secondary-growth forest of the moist zone (ca. 60% of the total land area of Puerto Rico) is dominated by species such as the Puerto Rico royal palm (*Roystonea borinquena*), West Indies trema (*Trema lamarckiana*), trumpet

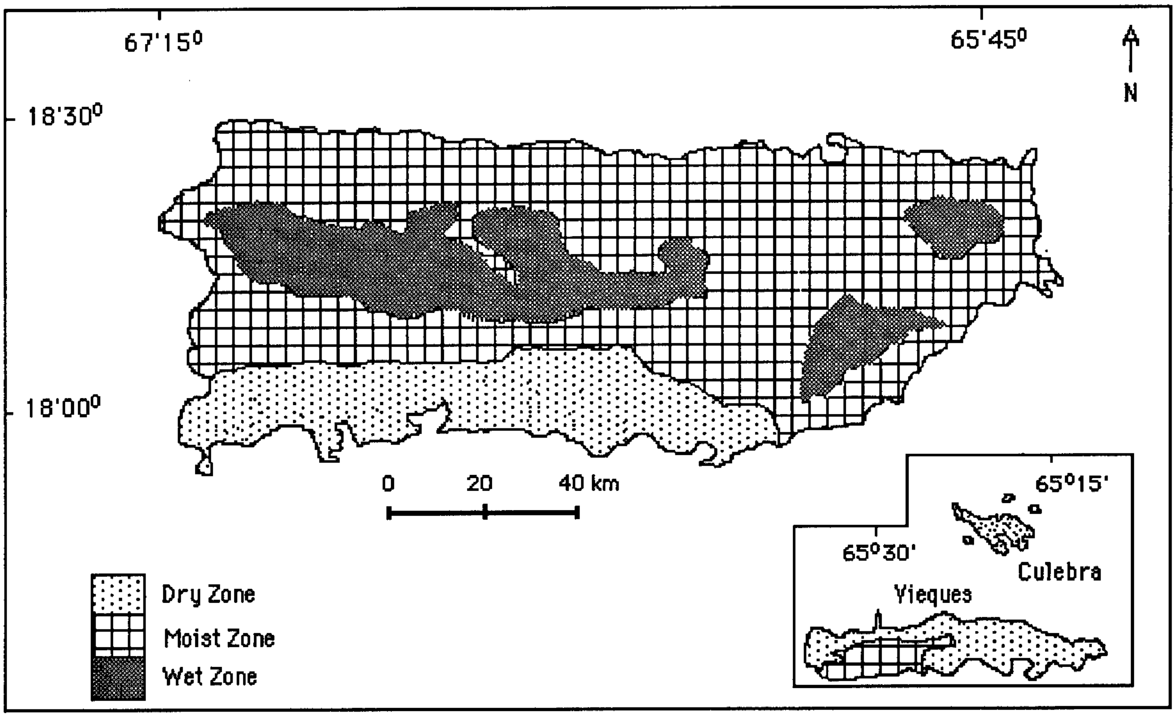


Fig. 2. The three major life zones on Puerto Rico and its two major offshore territories, the Vieques and Culebra islands.

tree (*Cecropia shreberiana*), India laurel fig (*Ficus citrifolia*), machette (*Erythrina berteroana*), mountain immortelle (*E. poeppigiana*), guaba (*Inga vera*), Martinique prickly-ash (*Zanthoxylum martinicence*), American muskwood (*Guarea trichilioides*), wild-mamee (*Clusia rosea*), punchberry (*Myrcia splendens*), apple rose (*Syzygium jambos*), matchwood (*Didymopanax morototoni*), white manjack (*Cordia sulcata*), night shade (*Solanum torvum*), African tuliptree (*Spathodea campanulata*), white cedar (*Tabebuia heterophylla*), and species of *Nectandra* and *Ocotea* (commonly known as "laureles") among others (Ewel and Whitmore 1973; Little et al. 1977; Birdsey and Weaver 1982; Silander et al. 1986).

Zenaida doves, mourning doves, and common ground-doves are mainly ground-dwellers in mixed and open woodlands in the dry, moist, and wet zones (Pérez-Rivera 1987; Rivera-Milán 1990a; Wiley 1991). White-winged doves are more arboreal than zenaida doves, mourning doves, and common ground-doves and are commonly seen in coastal dry areas dominated by mangrove forest. Scaly-naped pigeons and plain pigeons are mainly arboreal and prefer low and high montane forests in the wet and moist zones (Pérez-Rivera and Collazo-Algarín 1976; Rivera-Milán 1990a). Ruddy quail-doves, Key West quail-doves, and bridled quail-doves are mainly ground-dwellers that frequent the understory of low and high montane forests in the moist and wet zones (Pérez-Rivera 1979; Rivera-Milán 1990a). White-crowned pigeons are mainly arboreal and prefer mangrove forests (Wiley 1979; Wiley and Wiley 1979).

Roadside Counts

In July 1985, 15 routes (5/life zone) were randomly selected from a pool of 36 possible choices on the Puerto Rican mainland. In May 1991, the number of routes was increased to 31 on the Puerto Rican mainland (16 in the wet zone, 9 in the moist zone, and 6 in the dry zone), and 3 routes

were established on Vieques Island. The routes were along secondary and tertiary roads that were lightly traveled during the early morning hours. Each route on the Puerto Rican mainland was 8 km long (Fig. 3). The lengths of the routes on Vieques Island were 3.2 km (road 995), 4 km (Camp García and road 997), and 8 km (Naval Base Storage Facility).

Six permanent sampling stations per route were established at regular intervals of 1.6 km on the Puerto Rican mainland. The stations were 0.8 km from each other on Vieques Island (i.e., 4 stations along road 995, 6 stations in Camp García and road 997, and 10 stations inside the Naval Base Storage Facility). The first station of each route represented a random start. Orange fluorescent paint was used to mark the stations of each route. Counts were conducted for 3 min at each station. During the 3 min, the number of heard and sighted pigeons and doves was recorded on standard data sheets. Each observation was classified as aural or visual by the initial form of detection. The total number of calls per individual (the calling rate) was recorded when possible.

While driving between stations, the observers kept a separate record of the observed individuals per species. The driving speed between stations fluctuated between 16 and 32 kph. Other recorded data were disturbance level (e.g., traffic) and general weather conditions. Counts were conducted from 0600 to 1030 h but were suspended when it was raining or if the wind exceeded 19 kph. The starting time in montane habitats of the moist and wet zones was usually delayed by early-morning fog and drizzle. From July 1985 to May 1990, sampling on the routes was conducted by the same observers (Rivera-Milán 1990a; Rivera-Milán et al. 1990). New observers were needed in May 1991 and 1992 when the number of routes was doubled (Ramos et al. 1991).

Routes of 8 km (or fewer km on Vieques Island) were established because of the availability of secondary and tertiary roads in rural and suburban areas. The length of the routes also facilitated the task of sampling a representative portion of the large set of habitats (from coastal dry forests to low and high montane moist and wet forests) occupied by generalists such as zenaida doves and common ground-doves in the life zones.

In July 1986, the sampling scheme of the roadside counts was expanded to include all 10 native species of the columbids, and detection distances were defined as unfixed and fixed at 60 m from the center of 3-min stations. Here I provide data from only unfixed roadside counts. Unfixed roadside counts required less training of personnel than fixed roadside counts and provided enough information to examine the most general patterns of the distribution and relative abundance of the columbids in Puerto Rico and on Vieques Island (Rivera-Milan 1990a, 1992, unpublished data).

Statistical Analyses and Sample-size Estimates

I used four variables (number of calling individuals per species per km, number of seen individuals per species per km, number of total detections [aural + visual] per species per km, and number of calls per individual of each species per km) to generate descriptive statistics and estimate the number of within-year sampling units (8-km routes) needed per life zone to obtain confidence limits of ±10–50% during the May–June counting period. Means and variances per life zone (stratum) were estimated with the equations for a simple random sampling design (Scheaffer et al. 1979). Overall means and variances (life zones pooled) were estimated with the equations for a stratified random-sampling design (Scheaffer et al. 1979). When working with relative abundance indices, within-year sample sizes per life zone were estimated following the equations given by Eberhardt (1978).

Scattergrams, line charts, and box plots were used to delineate the distribution and relative-abundance patterns of the columbids in the life zones of the Puerto Rican mainland and Vieques Island. Box plots were used to depict 5-percentile ranks (10th, 25th, 50th, 75th, and 90th) of the annual call-count surveys of the columbids on the Puerto Rican mainland (May 1987–92) and on Vieques Island (May 1991 and 1992). Pearson's Product–Moment Coefficient of Correlation (r) was used to measure the intensity of the association between pairs of variables. A multivariate analysis of variance (MANOVA) and analysis of covariance (ANCOVA) were used to examine the

a

b

c

Fig. 3. Sampling was conducted on 8-km (5-mile) routes in (A) coastal dry forests and in (B) low and (C) high montane moist and wet forests. *Photos by D. Ramos.*

effects of four variables (observer, starting and finishing time per route, and disturbance level per route) on the mean number of calling zenaida doves and scaly-naped pigeons per km each year in the life zones (May 1987–92). Call-count surveys between the second week of May and the second week of June (1987–92) were used in the examination of annual trends of the zenaida doves and scaly-naped pigeons with simple linear regression; ANOVA with year effects nested within the routes of each life zone were used to account for local habitat changes (Geissler and Noon 1981; Geissler 1984). Paired *t*-tests and Student–Newman-Keuls (SNK) multiple-comparisons procedure were performed as follow-up tests of significance (Sokal and Rohlf 1981; Day and Quinn 1989). Route-to-route variation was considered a major component of the total variation of the annual call-count surveys in the life zones and was used in the calculation of the variances and confidence intervals of the weighted means (James et al. 1990).

Only data that were collected by experienced observers (≥3 years) were included in the examination of annual call-count trends. The data were analyzed before and after being log-transformed ($\log_{10}x + 0.5$). Because many factors that influenced the call-count surveys acted as multipliers, the log-transformation was used to restore the additivity of the data (Eberhardt 1978; Sokal and Rohlf 1981; Geissler 1984; Rivera-Milán 1990a, 1992). In the absence of discrepancies, the non-transformed data were used to depict trends. A trend was defined as a rate of change in a relative abundance over time (6 years) and space (the routes of each life zone). Results were considered significant at $P \leq 0.05$.

Results

Seasonal Descriptive Statistics of Roadside Counts on the Puerto Rican Mainland

Means and standard deviations (SD) of the roadside counts of the columbids positively correlated ($r = 0.9$; Fig. 4a). Hence the coefficient of variance (CV) was used as a measure of the variability of the counts. Coefficients of variance of the roadside counts fluctuated according to the established spa-

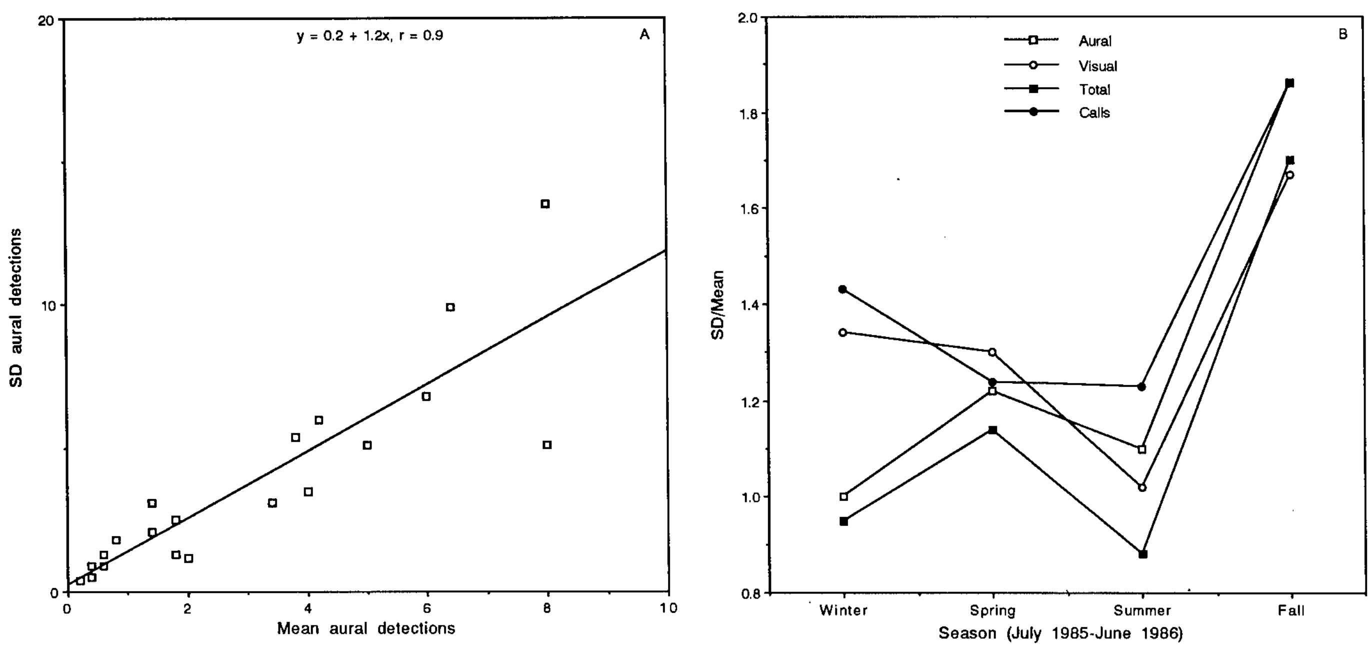


Fig. 4. **(A)** Mean versus standard deviation (SD) of the roadside counts of the zenaida doves and scaly-naped pigeons in the sampling units (n = 15 routes, each 8 km long) of the three major life zones of the Puerto Rican mainland. **(B)** Ratio of SD to the mean number of aural and visual detections of the scaly-naped pigeons and zenaida doves (pooled) per km in the three major life zones of the Puerto Rican mainland, July 1985–June 1986 (Collazo et al. 1985; Moreno et al. 1986).

tial (e.g., life zone) and temporal (e.g., season) scales. The most variable index of the relative abundance was the mean number of calls per individual of each species per km (the calling rate), and the next most variable indexes were the mean number of seen individuals per species per km (the visual count survey), the mean number of calling individuals per species per km (the call-count survey), and the mean number of total detections (aural + visual) per species per km (the total count survey; Fig. 4b).

Zenaida Doves

The mean number of calling zenaida doves per km in the three major life zones of the Puerto Rican mainland peaked during spring (Table 1; Fig. 5a). Coefficients of variance of the call-count

Table 1. Seasonal descriptive statistics of the call-count surveys of the zenaida doves (*Zenaida aurita*) in the three major life zones of the Puerto Rican mainland.[a]

Zone	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Dry					
Winter (1)	7.0	3.5	49.5	-1.6–15.6	3
Winter (2)	5.3	2.5	47.2	-0.9–11.6	3
Spring (1)	22.7	16.4	72.5	-18.2–63.5	3
Spring (2)	23.3	5.7	24.4	9.2–37.5	3
Summer (1)	10.2	6.7	62.4	-5.6–27.2	3
Summer (2)	10.7	15.1	142.0	-26.9–48.3	3
Fall (1)	3.0	5.2	173.0	-9.9–15.9	3
Fall (2)	6.0	6.0	100.0	-8.9–20.9	3
Moist					
Winter (1)	7.0	1.0	14.3	4.5– 9.5	3
Winter (2)	11.7	13.9	118.9	-22.8–46.1	3
Spring (1)	21.3	5.0	23.6	8.8–33.8	3
Spring (2)	22.3	19.7	88.3	-26.7–71.3	3
Summer (1)	10.7	12.2	114.6	-19.7–41.0	3
Summer (2)	10.7	11.0	103.3	-16.7–30.0	3
Fall (1)	4.0	4.3	109.0	-6.8–14.8	3
Fall (2)	0.7	0.6	86.7	-0.8– 2.1	3
Wet					
Winter (1)	0.3	0.6	173.2	-1.1– 1.8	3
Winter (2)	0.0				3
Spring (1)	4.0	2.0	50.0	-1.0– 9.0	3
Spring (2)	1.3	0.6	43.3	-0.1– 2.8	3
Summer (1)	1.0	1.7	173.2	-3.3– 5.3	3
Summer (2)	0.0				3
Fall (1)	0.0				3
Fall (2)	0.0				3

[a] Fifteen 8-km sampling units (routes) were used from July 1986 to June 1988. Five sampling units per life zone were established at random in secondary and tertiary roads. The call-count surveys included nest ("oooa-oo-oo-oo") and advertisement ("coo-coo-coo") calls of the species (Wiley 1991). The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling zenaida doves per 40 km (i.e., 5 8-m routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean 1.96SD/$(n)^{0.5}$.

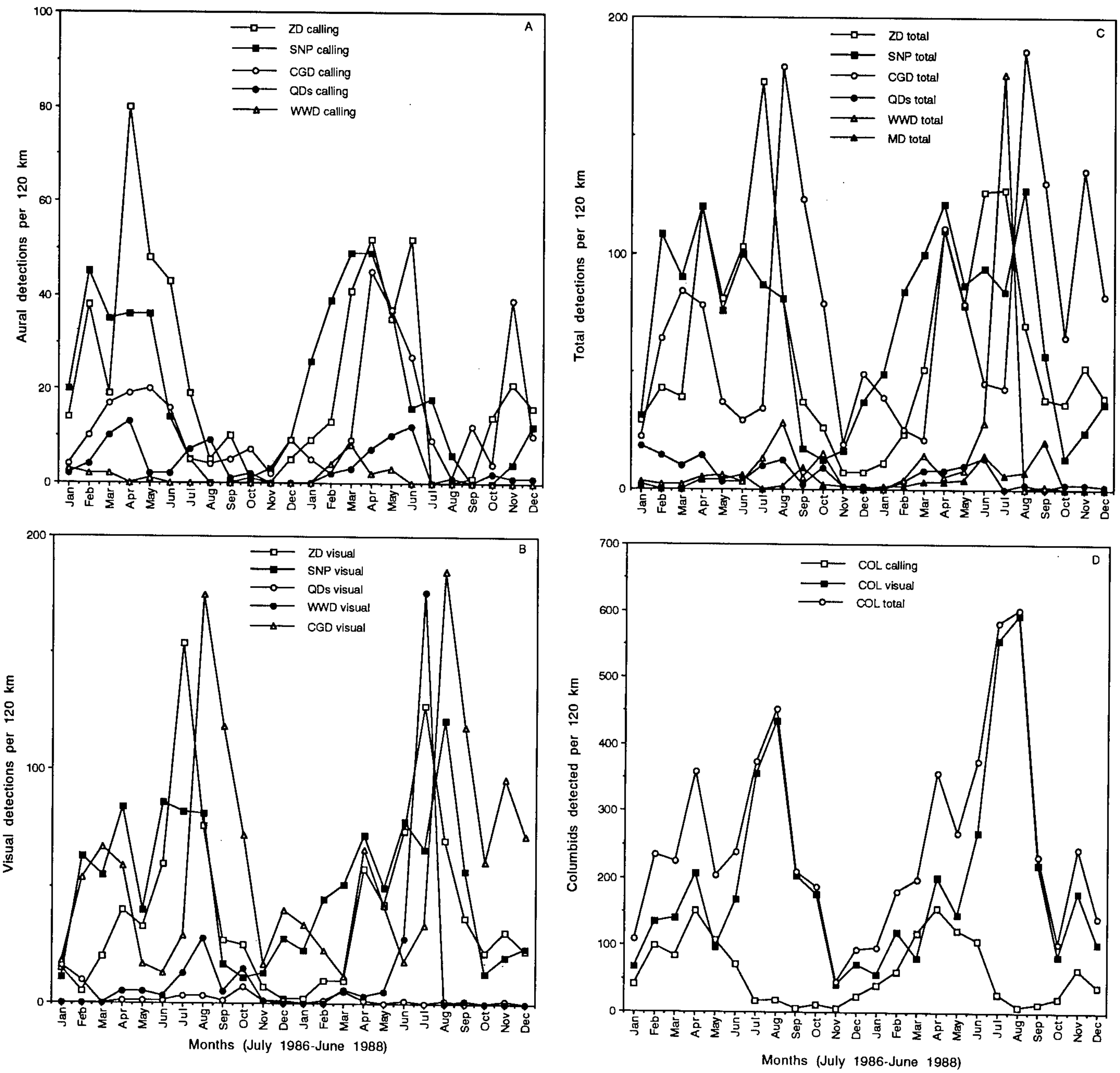


Fig. 5. Roadside counts of the 10 native species of pigeons and doves in the three major life zones of the Puerto Rican mainland. Columbids were sampled in 15 units (i.e., 120 km) once per month from July 1986 to June 1988. (A) The number of aural detections per 120 km. (B) The number of visual detections per 120 km. (C) The number of total (aural + visual) detections per 120 km. (D) The number of aural, visual, and total detections per 120 km of the 10 native species (pooled). Abbreviations: scaly-naped pigeons (SNP), white-winged doves (WWD), zenaida doves (ZD), mourning doves (MD), common ground-doves (CGD), quail-doves (QDs: ruddy, Key West, and bridled quail-doves pooled), and all columbids (COL).

surveys ranged from 24.4 to 173.0% in the dry zone, from 14.3 to 114.6% in the moist zone, and from 43.3 to 173.2% in the wet zone. Coefficients of variance in spring (23.6–50.0%) were relatively lower than CVs in winter (14.3–173.2%), summer (62.4–173.2%), and fall (86.0–173.0%; Table 1; Fig. 5a). Zenaida doves were relatively more abundant in the dry and moist zones than in the wet zone (Rivera-Milán 1990a, 1992).

Scaly-naped Pigeons

The mean number of calling scaly-naped pigeons per km peaked during spring in the wet and moist zones of the Puerto Rican mainland (Table 2 and Fig. 3a). Coefficients of variance of the call-count surveys ranged from 11.9 to 107.8% in the moist zone and from 3.6 to 173.2% in the wet zone. Coefficients of variance in spring (3.6–19.9%) were relatively lower than CVs in winter (48.3–95.3%), summer (43.6–114.6%), and fall (100.0–173.2%; Table 2; Fig. 3a). The relative abundance of the scaly-naped pigeons was higher in the wet zone than in the moist zone (Rivera-Milán 1990a, 1992). Calling scaly-naped pigeons were not detected in the dry zone from July 1986 to June 1988. They were rarely seen in the xerophytic and dry coastal forests of the dry zone (south and southwestern Puerto Rico).

Common Ground-doves

The mean number of calling common ground-doves per km in the dry and moist zones of the Puerto Rican mainland peaked during spring (Table 3; Fig. 5a). Coefficients of variance of the

Table 2. Seasonal descriptive statistics of the call-count surveys of the scaly-naped pigeons (*Columba squamosa*) in the two major life zones of the Puerto Rican mainland.[a]

Zone	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Moist					
Winter (1)	6.0	4.0	66.7	-3.9-15.9	3
Winter (2)	6.0	3.0	50.0	-1.4-13.4	3
Spring (1)	9.7	1.1	11.9	6.8-12.5	3
Spring (2)	7.7	1.5	19.9	-3.9-11.5	3
Summer (1)	3.0	3.0	100.0	-4.4-10.4	3
Summer (2)	2.3	2.5	107.8	-3.9- 8.6	3
Fall (1)	0.0				3
Fall (2)	1.0	1.0	100.0	-1.5- 3.5	3
Wet					
Winter (1)	19.7	9.5	48.3	-3.9-43.3	3
Winter (2)	18.7	17.8	95.3	-25.5-62.8	3
Spring (1)	35.3	6.4	18.2	19.4-51.3	3
Spring (2)	28.0	1.0	3.6	25.5-30.5	3
Summer (1)	10.3	4.5	43.6	-0.9-21.5	3
Summer (2)	4.0	4.6	114.6	-7.3-15.4	3
Fall (1)	1.3	2.3	173.2	-4.4- 7.1	3
Fall (2)	0.3	0.6	173.2	-1.1- 1.8	3

[a] The call-count surveys included nest ("growls") and advertisement ("who-are-you") calls of the species. Five scaly-naped pigeons were detected in the sampling units of the dry zone from July 1986 to June 1988. The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling scaly-naped pigeons per 40 km (i.e., 5 8-km routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean $1.96SD/(n)^{0.5}$.

Table 3. Seasonal descriptive statistics of the call-count surveys of the common ground-doves (*Columbina passerina*) in the dry and moist zones of the Puerto Rican mainland.[a]

Zone	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Dry					
Winter (1)	7.3	3.0	41.6	-0.3–14.9	3
Winter (2)	5.3	4.5	84.5	-5.9–16.5	3
Spring (1)	17.3	2.3	13.3	11.6–23.1	3
Spring (2)	28.0	17.1	60.9	-14.4–70.4	3
Summer (1)	7.0	5.2	74.2	-5.9–19.9	3
Summer (2)	11.0	12.8	116.1	-20.7–42.7	3
Fall (1)	4.0	2.0	50.0	-1.0– 9.0	3
Fall (2)	18.0	17.8	98.8	-26.2–62.2	3
Moist					
Winter (1)	0.7	0.6	86.6	-0.8– 2.1	3
Winter (2)	0.3	0.6	173.2	-1.1– 1.8	3
Spring (1)	1.3	1.5	114.5	-2.5– 5.1	3
Spring (2)	2.3	2.1	89.2	-2.8– 7.5	3
Summer (1)	1.3	1.5	114.5	-2.5– 5.1	3
Summer (2)	1.0	1.0	100.0	-1.5– 3.5	3
Fall (1)	0.7	0.6	86.6	-0.8– 2.1	3
Fall (2)	0.3	0.6	173.2	-1.1– 1.8	3

[a] Five common ground-doves were detected in the sampling units of the wet zone from July 1986 to June 1988. The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling common ground-doves per 40 km (i.e., 5 8-km routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean 1.96SD/$(n)^{0.5}$.

call-count surveys ranged from 13.3 to 116.1% in the dry zone and from 86.6 to 173.2% in the moist zone. Coefficients of variance in spring (13.3–114.5%) were relatively lower than CVs in winter (41.6–173.2%), summer (74.2–114.6%), and fall (50.0–173.2%; Table 3; Fig. 5a). Common ground-doves were relatively more abundant in the dry zone than in the moist zone (Rivera-Milán 1990a, 1992). They were rarely heard in the wet zone.

Quail-doves

The mean number of calling ruddy, Key West, and bridled quail-doves (pooled) per km in the moist and wet zones of the Puerto Rican mainland peaked during spring-summer (Table 4; Fig. 5a). Coefficients of variance of the call-count surveys ranged from 8.6 to 173.2% in the wet zone and from 43.3 to 173.2% in the moist zone. Coefficients of variance in spring–summer ranged from 43.3 to 173.2%; CVs in winter ranged from 8.6 to 173.2%; and CVs in the falls of 1986 and 1987 were both 173.2% (Table 4; Fig. 3a). The three species of quail-doves were relatively more abundant in the moist zone than in the wet zone (Rivera-Milán 1990a, 1992). Quail-doves were not heard in the dry zone. Ruddy and Key West quail-doves were infrequently seen from the route in the xerophytic forest of Guánica. They were never detected from the routes in the dry coastal forests of south and southwestern Puerto Rico.

White-winged Doves

The mean number of calling white-winged doves per km in the dry zone of the Puerto Rican mainland

Table 4. Seasonal descriptive statistics of the call-count surveys of the ruddy quail-doves (*Geotrygon montana*), Key West quail-doves (*G. chrysia*), and bridled quail-doves (*G. mystacea*; pooled) in the moist and wet zones of the Puerto Rican mainland.[a]

Zone	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Moist					
Winter (1)	2.3	2.5	107.8	-4.0- 8.6	3
Winter (2)	0.7	1.2	173.2	-2.2- 3.5	3
Spring (1)	4.3	4.0	93.3	-5.7-14.4	3
Spring (2)	5.0	2.6	52.9	-1.6-11.6	3
Summer (1)	4.0	1.7	43.3	-0.3- 8.3	3
Summer (2)	3.0	5.2	173.2	-9.9-15.9	3
Fall (1)	0.7	1.1	173.2	-2.2- 3.5	3
Fall (2)	0.7	1.1	173.2	-2.2- 3.5	3
Wet					
Winter (1)	0.0				3
Winter (2)	0.7	0.6	86.6	-0.8- 2.1	3
Spring (1)	2.7	3.8	142.0	-6.7-12.1	3
Spring (2)	1.3	1.5	114.6	-2.5- 5.1	3
Summer (1)	2.3	2.1	89.2	-2.8- 7.5	3
Summer (2)	1.3	1.5	114.6	-2.5- 5.1	3
Fall (1)	0.3	0.6	173.2	-1.1- 1.8	3
Fall (2)	0.0				3

[a] Six ruddy quail-doves and 12 Key West quail-doves were detected in the sampling units of the dry zone from July 1986 to June 1988. Bridled quail-doves were not detected from the routes in the dry zone during the sampling period. The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling quail-doves per 40 km (i.e., 5 8-km routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean 1.96SD/$(n)^{0.5}$.

peaked during winter–spring, and CVs ranged from 34.6 to 173.2% in the dry zone (Table 5; Fig. 5a). White-winged doves were not heard in the wet and moist zones. Single-species flocks of variable sizes were observed during summer–fall in agricultural areas of the dry, moist, and wet zones (Rivera-Milán 1990a).

Mourning Doves

The mean number of calling mourning doves per km in the dry zone of the Puerto Rican mainland peaked during winter–spring, and CVs ranged from 43.3 to 173.2% in the dry zone (Table 6). Mourning doves were not heard in the wet and moist zones. Single- and mixed-species flocks (usually mourning doves and zenaida doves) were observed during summer–fall in agricultural areas of the dry, moist, and wet zones (Rivera-Milán 1990a).

Columbids (Pooled)

The mean number of calling columbids per km peaked during spring in the three major life zones (pooled) of the Puerto Rican mainland. Coefficients of variance were relatively lower in spring (15.8–29.9%) than in winter (25.6–72.3%), summer (90.5–111.0%), and fall (43.8–86.4%; Table 7).

The number of visual detections per km peaked during summer–fall when single- and mixed-species flocks of variable sizes were observed in foraging areas throughout the Puerto Rican mainland (Fig. 5b). The number of total detections per km peaked during spring because of an increase

Table 5. Seasonal descriptive statistics of the call-count surveys of the white-winged doves (*Zenaida asiatica*) in the dry zone of the Puerto Rican mainland.[a]

Season	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Winter (1)	1.0	1.0	100.0	-1.5- 3.5	3
Winter (2)	1.3	2.3	173.2	-4.4- 7.1	3
Spring (1)	1.7	0.6	34.6	0.2- 3.1	3
Spring (2)	6.7	8.1	122.2	-13.6-26.9	3
Summer (1)	0.0				3
Summer (2)	0.0				3
Fall (1)	0.0				3
Fall (2)	0.0				3

[a] Calling white-winged doves were not heard from the routes in the moist and wet zones from July 1986 to June 1988. Flocks of variable sizes were detected during summer–fall in agricultural areas of the dry, moist, and wet zones (Rivera-Milán 1990a). The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling white-winged doves per 40 km (i.e., 5 8-km routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean $1.96SD/(n)^{0.5}$.

Table 6. Seasonal descriptive statistics of the call-count surveys of the mourning doves (*Zenaida macrouda*) in the dry zone of the Puerto Rican mainland.[a]

Season	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Winter (1)	0.3	0.6	173.2	-1.1-1.8	3
Winter (2)	0.3	0.6	173.2	-1.1-1.8	3
Spring (1)	1.3	0.6	43.3	-0.1-1.8	3
Spring (2)	0.7	1.1	173.2	-2.2-3.5	3
Summer (1)	0.0				3
Summer (2)	0.0				3
Fall (1)	0.0				3
Fall (2)	0.0				3

[a] Calling mourning doves were not heard from the routes in the moist and wet zones from July 1986 to June 1988. Visual detections occurred during summer–fall in agricultural areas of the dry, moist, and wet zones (Rivera-Milán 1990a). The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling mourning doves per 40 km (i.e., 5 8-km routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean $1.96SD/(n)^{0.5}$.

Table 7. Seasonal descriptive statistics of the call-count surveys of the columbids in the three major life zones (pooled) of the Puerto Rican mainland.[a]

Season	Mean[b]	SD[c]	CV[d] (%)	95% CL[e]	Counts
Winter (1)	54.7	39.5	73.3	-43.6–152.9	3
Winter (2)	46.3	11.8	25.6	16.9– 75.8	3
Spring (1)	114.0	34.0	29.9	29.4–198.6	3
Spring (2)	132.0	20.9	15.8	80.1–183.9	3
Summer (1)	36.7	33.2	90.5	-45.8–119.1	3
Summer (2)	47.3	52.5	111.0	-83.2–177.8	3
Fall (1)	7.3	3.2	43.8	-0.6– 15.3	3
Fall (2)	32.7	28.2	86.4	-37.4–102.8	3

[a] The call-count surveys included all 10 native species. Sampling was conducted from 15 routes (i.e., 120 km) once per month from July 1986 to June 1988. The number of calling individuals was recorded on standard data sheets.

[b] Mean of calling native species per 40 km (i.e., 5 8-km routes). Seasonal arithmetic means were calculated by pooling call counts per month per life zone as follows: winter—December, January, and February; spring—March, April, and May; summer—June, July, and August; fall—September, October, and November. Three call counts per route per season were conducted in the life zones.

[c] Sample standard deviation (Scheaffer et al. 1979: Chapter 4).

[d] SD/mean × 100.

[e] Mean 1.96SD/$(n)^{0.5}$.

in the number of aural and visual detections per km before and during the reproductive peak (May–June) and between the summer and fall because of an increase in the number of visual detections per km during the flocking period (Figs. 5c and 5d).

Annual Descriptive Statistics of Call-count Surveys of Zenaida Doves and Scaly-naped Pigeons on the Puerto Rican Mainland

The annual CVs of the call-count surveys of the zenaida doves were in the order of 109–178% (15 sampling units pooled; mean CV = 141%; Fig. 6a). Similarly, the annual CVs of the call-count surveys of the scaly-naped pigeons were in the order of 76–130% (10 sampling units pooled; mean CV = 101%; Fig. 6b).

The call-count surveys seemed less skewed of the scaly-naped pigeons than of the zenaida doves (i.e., the box plots had a more symmetrical appearance because the medians were closer to the middle; compare, for example, the call counts of May 1991). However, the box plots were thicker of the scaly-naped pigeons than of the zenaida doves (i.e., the middle 50% of the distribution of the call-count surveys was more heterogeneous of the scaly-naped pigeons than of the zenaida doves). The vertical lines associated with the higher counts (i.e., the lines extending from the 75th to the 90th percentiles) were longer than the vertical lines associated with the lower counts (i.e., the lines extending from the 20th to the 10th percentile) of both species, suggesting a positively skewed distribution of the data. As shown by the small circles below and above the vertical lines (i.e., the observed values below the 10th and above the 90th percentiles), the call-count surveys had more extreme values of the zenaida doves than of the scaly-naped pigeons. These extreme values provided an explanation for the greater variability associated with the call-count surveys of the zenaida doves in the life zones. The call-count surveys of the zenaida doves were more homogeneous than the call-count surveys of the scaly-naped pigeons; but the higher values of the counts of the zenaida doves were more extreme than the higher values of the counts of the scaly-naped pigeons. The zenaida doves were more commonly detected in flocks, pairs, and singles and were more widely distributed than scaly-naped pigeons in the dry and moist zones of the Puerto Rican mainland.

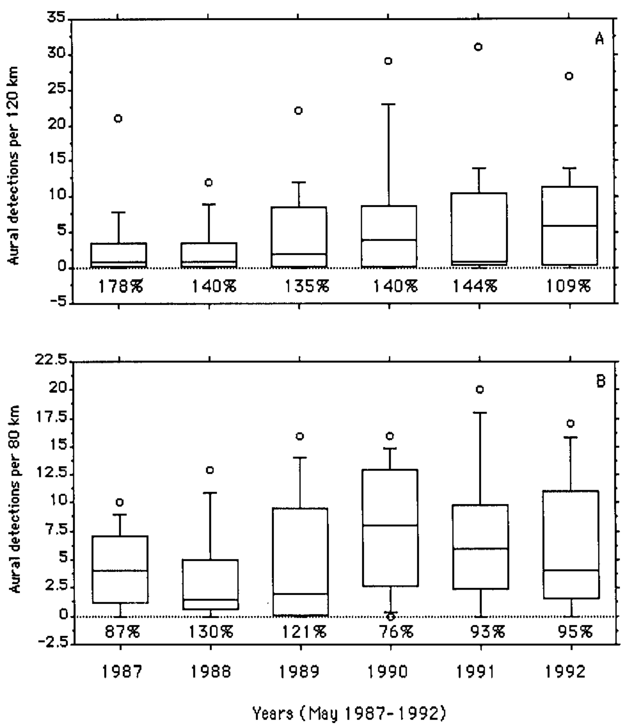


Fig. 6. Box plots of the annual call-count surveys (May 1987–92) of (A) zenaida doves (n = 15 routes) and (B) scaly-naped pigeons (n = 10 routes) on the Puerto Rican mainland. Scaly-naped pigeons were rarely observed from the routes of the dry zone. Five percentile ranks (10th, 25th, 50th, 75th, and 90th) were computed to construct the box plots. The *top* of each box represents the 50th percentile; the *line in the middle* of each box is the median; the *line extending above* each box is the 90th percentile, and the *line extending below* each box is the 90th percentile; the *circles* extending from the lines represent the values below the 10th percentile and above the 90th percentile. The coefficients of variance (CVs) of the annual call-count surveys of both species are below the box plots.

The log-transformation of the call-count data of both species helped in solving the problems associated with the positively skewed distributions and heterogeneous variances.

Annual Descriptive Statistics of Call-count Surveys on Vieques Island

As on the Puerto Rican mainland, means and standard deviations of the roadside counts on Vieques Island positively correlated (r = 0.9). The annual CVs of the call-count surveys were in the order of 48–101% of the zenaida doves and 94–117% of the common ground-doves. The annual CVs of the call-count surveys were in the order of 150–174% of the relatively less abundant and widely distributed scaly-naped pigeons and 310–348% of the relatively less abundant and widely distributed white-crowned pigeons. Coefficients of variance of the call-count surveys of the columbids (9 species pooled) were in the order of 53–66% (Fig. 7). The basic statistical properties of the call-count surveys on Vieques Island and on the Puerto Rican mainland were similar (e.g., the vertical lines representing the 90th percentile of the counts were larger than those representing the 10th percentile, which is characteristic of a positively skewed distribution; the symmetry of the box plots varied by species and year; and the variances were heterogeneous).

Sample-size Estimates on the Puerto Rican Mainland

Coefficients of variance of the call-count surveys of the columbids (9 species pooled) declined weakly as the number of sampling units (3-min stations) was increased from 6 to 20 on Vieques Island (May 1991–92; Fig. 8a). However, CVs of the call-count surveys of the zenaida doves increased as the number of sampling units (either 8-km routes or 3-min stations) was increased from 4 to 31 on the Puerto Rican mainland (May 1987–92) and from 6 to 20 on Vieques Island (May 1991–92; Figs. 8b and 8c). Coefficients of variance of the call-count surveys of the scaly-naped pigeons increased slightly as the number of sam-

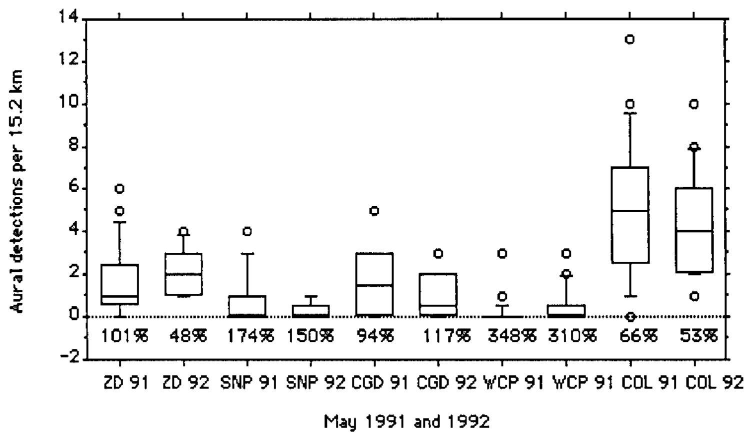


Fig. 7. Box plots of the annual call-count surveys (May 1991 and 1992) of columbids (9 species) on Vieques Island (n = 3 routes of unequal length; see Methods). Plain pigeons were not observed on Vieques Island during the sampling period. Abbreviations are as in Fig. 5, except for white-crowned pigeons (WCP). Coefficients of variance are below the box plots.

pling units (routes) was increased from 4 to 31 on the Puerto Rican mainland (May 1987–92) but declined weakly as the number of sampling units (3-min stations) was increased from 6 to 20 on Vieques island (May 1991–92; Figs. 8d and 8e).

Sample-size estimates of the columbids from the roadside counts varied by species, spatial and temporal scales, sensitivity (power of a test of a hypothesis), and precision (width of a confidence interval; Figs. 9a and 9b). At an α of 0.05 (z = 1.96) and a mean CV of 116% (May 1987–92), 538 sampling units (8-km routes) were required for confidence limits of 10% for the mean number of calling zenaida doves per km in the dry zone; with a mean CV of 95%, 361 sampling units were required for confidence limits of ±10% in the moist zone; and with a mean CV of 137%, 751 sampling units were required for confidence limits of ±10% in the wet zone. Similarly, at an α of 0.05 and a mean CV of 81% (May 1987–92), 262 sampling units were required for confidence limits of ±10% for the mean number of calling scaly-naped pigeons per km in the wet zone; and with a mean CV of 132%, 697 sampling units were required for confidence limits of ±10% in the moist zone.

The total count (aural + visual) surveys had lower CVs than the call-count surveys. For example, at an α of 0.05 and a mean CV of 104% (May 1987–92), 433 sampling units were required for confidence limits of ±10% for the mean number of total detections of zenaida doves per km in the dry zone; 108 sampling units were required for confidence limits of ±20%; 48 sampling units were required for confidence limits of ±30%; 27 sampling units were required for confidence limits of ±40%; and 17 sampling units were required for confidence limits of ±50% (Fig. 9b). Since May 1987, annual sampling has been conducted in 6 sampling units in the dry zone. At an α of 0.05 and a mean CV of 105%, 6 sampling units would have been required for confidence limits of ±85% for the mean number of total detections of zenaida doves per km in the dry zone.

Observer, Disturbance-level, and Time Effects

The effects of the four variables on the zenaida doves in the dry zone were nonsignificant (whole-model test: $F_{4,29}$ = 1.266, P = 0.305; observer-effect test: P = 0.423; disturbance-level-effect test: P = 0.849; starting-time-effect test: P = 0.237; finishing-time-effect test: P = 0.110); but in the moist zone, the starting and finishing time per route approached significance (whole-model test: $F_{4,25}$ = .360, P = 0.069; observer-effect test: P = 0.927; disturbance-level-effect test: P = 0.611; starting-time-effect test: P = 0.073; finishing-

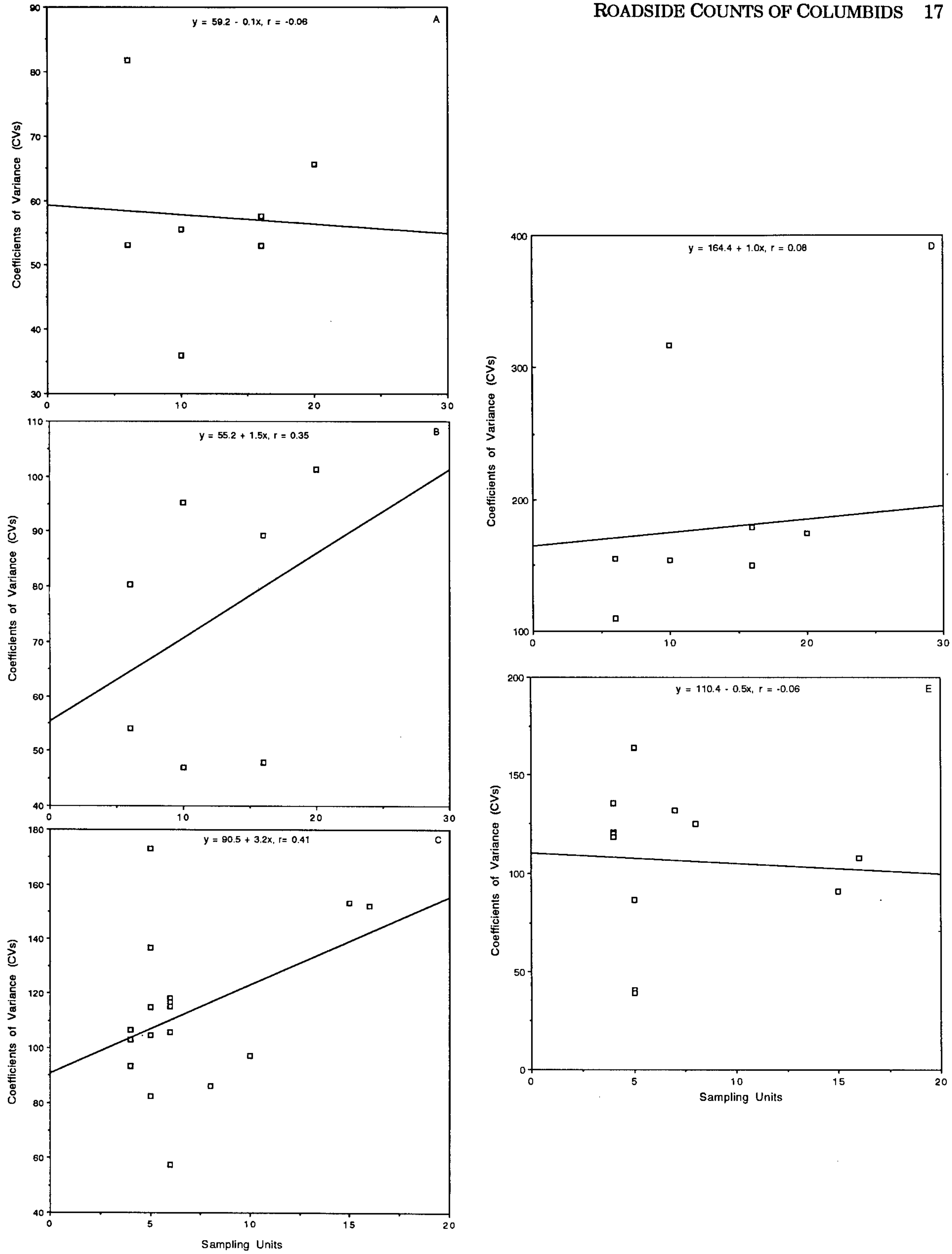


Fig. 8. Sampling units versus CVs of call-count surveys of columbids on Vieques Island (A); zenaida doves on Vieques Island (B) and on the Puerto Rican mainland (C); and scaly-naped pigeons on Vieques Island (D) and on the Puerto Rican mainland (E). Sampling was conducted from 20 3-min stations on 3 routes of unequal lengths on Vieques Island. Sampling was conducted on 15 8-km routes on the Puerto Rican mainland.

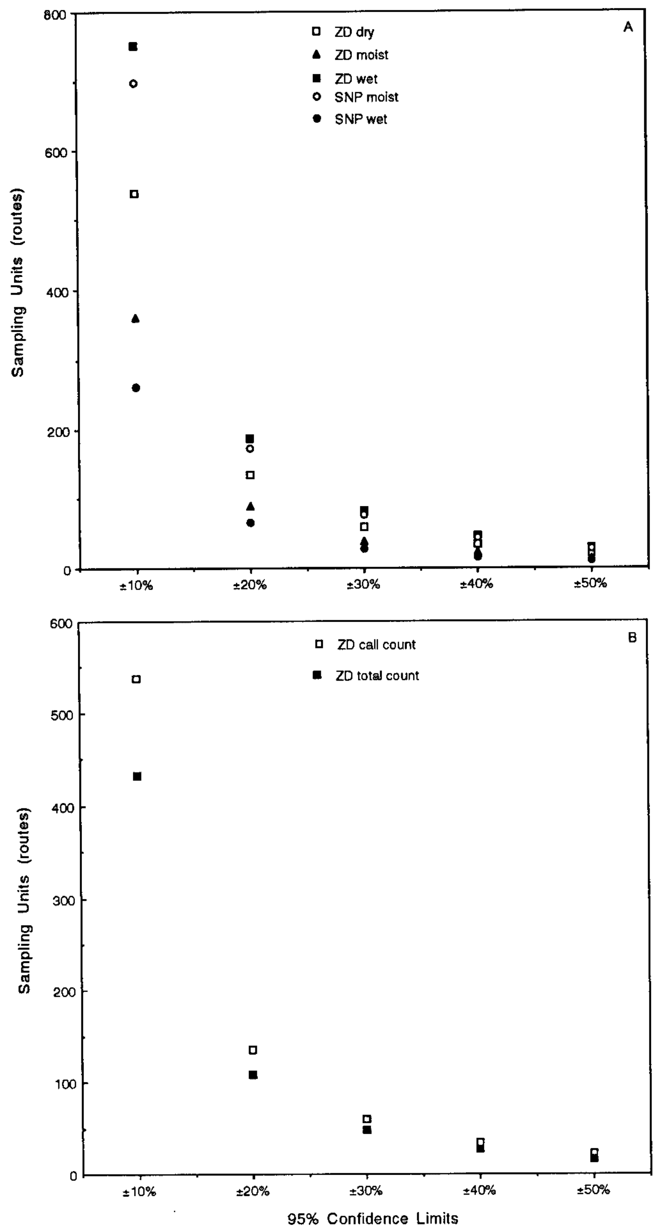


Fig. 9. (A) Number of within-year sampling units (8-km routes) required for confidence limits of ±10–50% for the mean number of calling scaly-naped pigeons and zenaida doves per km in the three major life zones of the Puerto Rican mainland. The mean CVs of the call- count surveys of zenaida doves (May 1987–92): dry zone = 115.8%, moist zone = 94.7%, and wet zone = 137.4%; the mean CVs of the call-count surveys of scaly-naped pigeons (May 1987–92): moist zone = 132.5% and wet zone = 81.0%. (B) Number of within-year sampling units required for confidence limits of ±10–50% for the mean number of aural and total (aural + visual) detections of zenaida doves in the dry zone of the Puerto Rican mainland. Mean CV of the total count surveys of zenaida doves (May 1987–92): dry zone = 104.7%. Sample sizes per life zone (stratum) were estimated with the equations given by Eberhardt (1978), May 1987–92 (Rivera-Milán et al. 1990; Ramos et al. 1991).

time-effect test: P = 0.095); and observer effects were significant in the wet zone (whole-model test: $F_{4,44}$ = 4.185, P = 0.003; observer-effect test: P = 0.001; disturbance-level-effect test: P = 0.967; starting-time-effect test: P = 0.389; finishing-time-effect test: P = 0.609). The effects of the four variables on the scaly-naped pigeons were non-significant in the wet zone (whole-model test: $F_{5,44}$ = 0.730, P = 0.605; observer-effect test: P = 0.140; disturbance-level-effect test: P = 0.926; starting-time-effect test: P = 0.803; finishing-time-effect test: P = 0.667) and in the moist zone (whole-model test: $F_{5,25}$ = 0.212, P = 0.954; observer-effect test: P = 0.683; disturbance-level-effect test: P = 0.918; starting-time-effect test: P = 0.577; finishing-time-effect test: P = 0.622).

The number of aural detections per km depended on the time spent sampling on each route

(i.e., finishing time), and this varied according to the experience of the observers, weather (e.g., early-morning fog and drizzle), and the conditions of the roads (e.g., secondary vs. tertiary roads) among other things. In the wet zone in May 1991 and 1992 and irrespective of the quality (e.g., low vs. high density of the columbids at routes, paved vs. unpaved roads) of the sampling units, new observers heard fewer zenaida doves per km than experienced observers.

Annual Calling Trends of Zenaida Doves and Scaly-naped Pigeons on the Puerto Rican Mainland

Similar call-count trends were obtained before and after log-transforming the data of the zenaida doves and scaly-naped pigeons. Because of the described effects of the observers and time on relative-abundance estimates, only data that were collected by experienced observers (≥3 years) were used in the analyses of the annual call-count trends.

The annual calling trend of the zenaida doves in the dry zone was nonsignificant (1987–92: y = 4.5 + 0.5[0.4 SE]x, r^2 = 0.2, df = 5, P = 0.32; Fig. 10a). A positive and significant calling trend of the zenaida doves was detected in the moist zone (1987–1992: y = 1.2 + 2.1[0.6 SE]x, r^2 = 0.8, df = 5, P = 0.02; Fig. 10b), and a nonsignificant calling trend was detected in the wet zone (1987–92: y = 0.3 + 0.2[0.1 SE]x, r^2 = 0.5, df = 5, P = 0.23; Fig. 10c).

There was a positive and significant calling trend in the scaly-naped pigeons in the wet zone (1987–92: y = 4.3 + 1.2[0.4 SE]x, r^2 = 0.7, df = 5, P = 0.04; Fig. 11a) but not in the moist zone (1987–92: y = 1.8 + 0.06[0.21 SE]x, r^2 = 0.02, df = 5, P = 0.80; Fig. 11b).

Similar annual trends were obtained after year effects were nested within the sampling units of the life zones (Figs. 12a and 12b). The calling trend of the zenaida doves in the moist zone remained significant ($F_{5,65}$ = 5.37, P < 0.001); the call-count surveys of the zenaida doves were significantly higher in May–June 1990 and 1991 than in May–June 1987 and 1988 (Paired t-tests and SNKs, P < 0.05). The calling trend of scaly-naped pigeons in the wet zone also remained significant ($F_{5,40}$ = 2.98, P = 0.02); the call-count surveys of scaly-naped pigeons were significantly higher in May–June 1990 than in May–June 1987 and 1988 (Paired t-tests and SNKs, P < 0.05). The overall (life zones pooled) call-count trend of the zenaida doves was positive and significant (weighted mean trend, May–June 1987–92: y = 1.5 + 1.1[0.3 SE]x, r^2 = 0.8, df = 5, P = 0.02; Fig. 12a); and the overall call-count trend of the scaly-naped pigeons approached significance (weighted mean trend, May–June 1987–92: y = 2.5 + 0.4[0.2 SE]x, r^2 = 0.5, df = 5, P = 0.09; Fig. 12b).

Discussion

Descriptive Statistics, Sample-size Estimates,and Call-count Surveys

The most variable index of the relative abundance of the columbids was the mean number of calls per individual of each species per km (the calling rate). Accurate and precise estimates of the calling rate of the individuals of each species per km were difficult to obtain, especially when several individuals of sometimes different species were calling repeatedly during the 3-min counts. The second most variable index of the relative abundance of the columbids was the mean number of seen individuals per species per km (the visual-count survey). The visual-count survey was influenced by the flocking behavior of the columbids. Flocks were highly detectable in foraging areas, especially after the reproductive peak (May–June). The mean number of calling individuals per species per km (the call-count survey) ranked third in terms of its variability and provided a suitable alternative to the estimated relative abundance of the columbids during the nesting season. The mean number of calling individuals per species per km in the three major life zones peaked during spring (March–May). Coefficients of variance of the call-count surveys were lower in spring than in winter, summer, and fall. The mean number of total detections (aural + visual) per km was the least variable of the indexes of the relative abundance of the columbids. The mean number of total detections per km peaked during spring because the number of aural and visual detections per km increased before and during the reproductive peak; and it peaked again during summer–fall because the number of visual detections per km

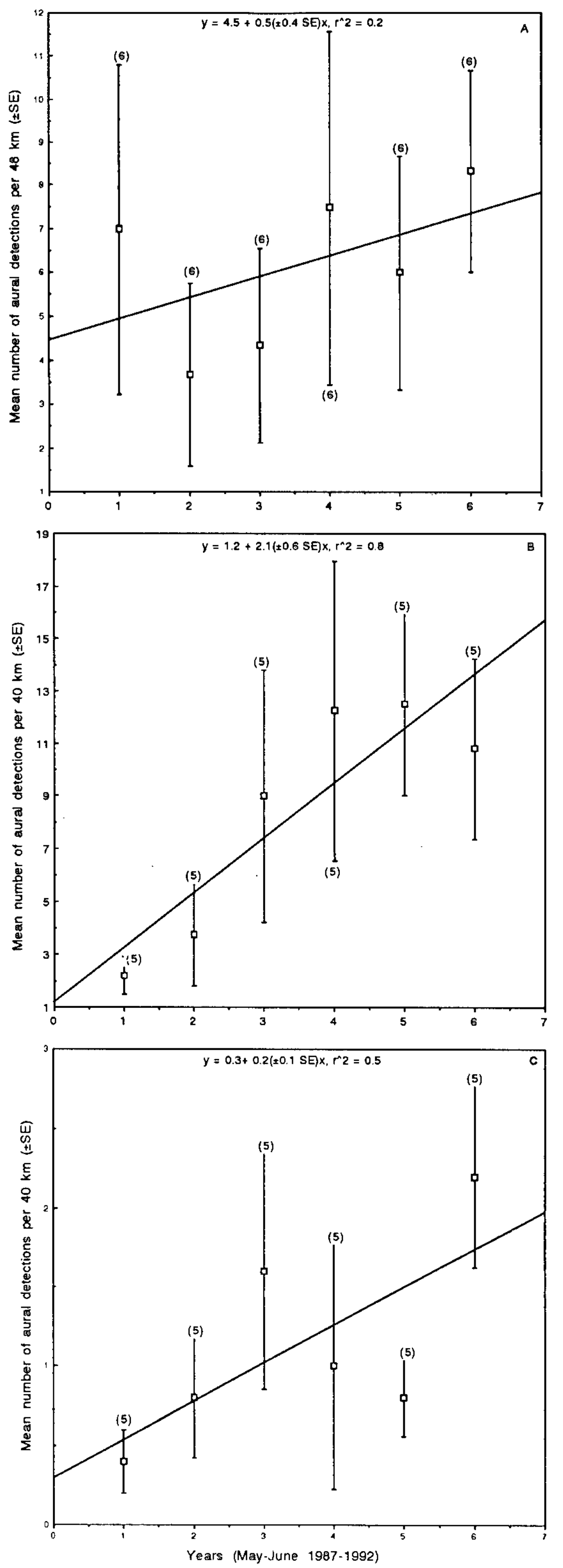


Fig. 10. Call-count trends of zenaida doves in the dry (A), moist (B), and wet (C) zones of the Puerto Rican mainland. The data are shown nontransformed. The *solid lines* represent simple linear regressions on the mean number of aural detections per life zone per year. The *vertical lines* represent the standard error (SE) of the means. The *numbers inside the parentheses* represent the routes. The same routes were used for sampling by the same observers from the second week of May to the second week of June (1987–92).

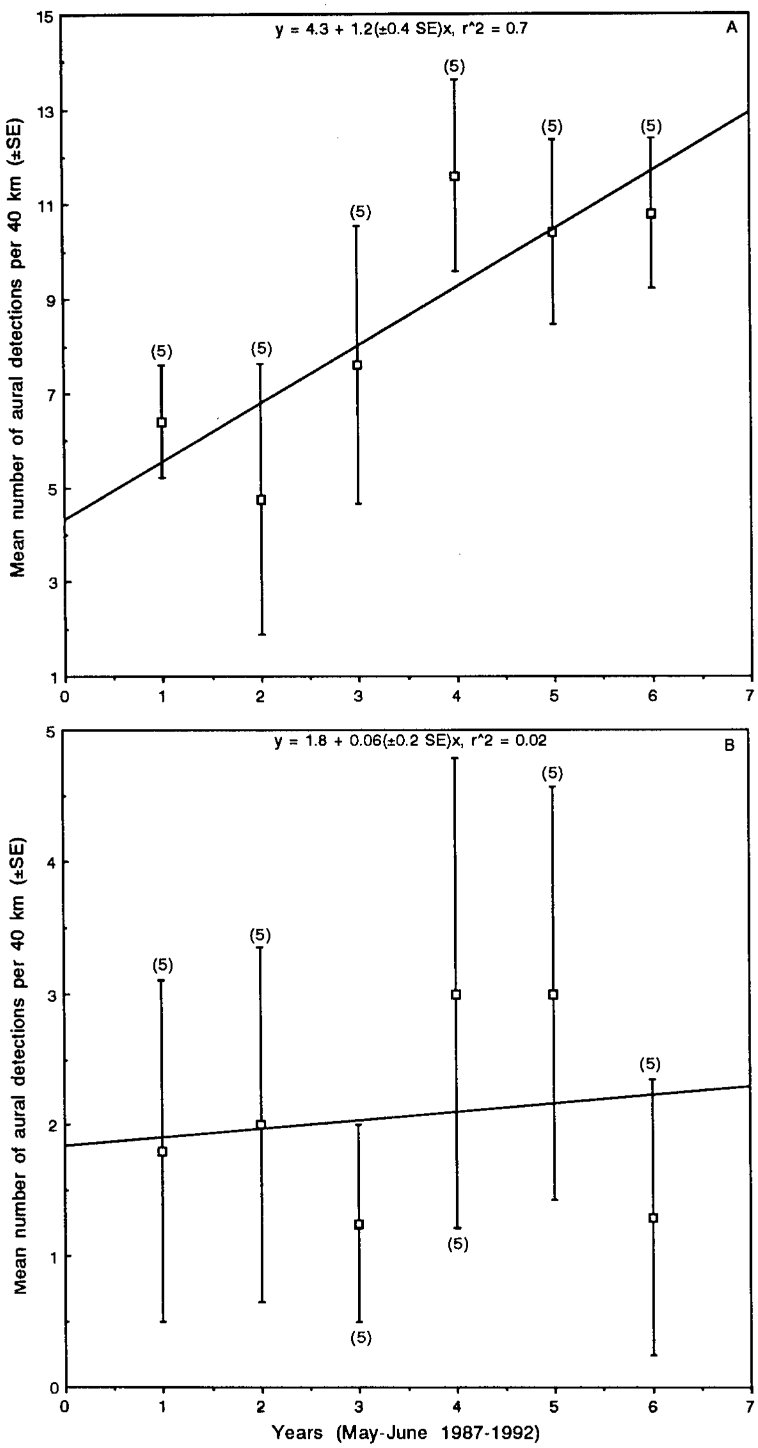


Fig. 11. Call-count trends of scaly-naped pigeons in the wet (A) and moist (B) zones of the Puerto Rican mainland. The data are shown nontransformed. The *solid lines* represent simple linear regressions on the mean number of aural detections per life zone per year. The *vertical lines* represent the standard error (SE) of the means. The *numbers inside the parentheses* represent the routes. The same routes were used for sampling by the same observers from the second week of May to the second week of June (1987–92).

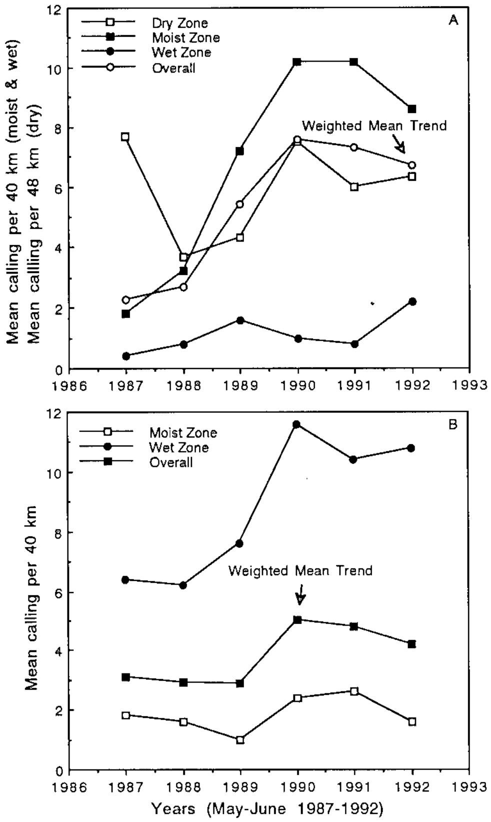


Fig. 12. Trends of zenaida doves (A) and scaly-naped pigeons (B) with route-to-route variability as a major source of the variance of call-count surveys on the Puerto Rican mainland. The weighted mean trends of the zenaida doves (A) and scaly-naped pigeons (B) were based on the area covered by the surveys in the life zones (pooled), May–June 1987–92.

increased as flocks became more conspicuous in areas with abundant food (e.g., agricultural areas).

Coefficients of variance of the roadside counts were rather high and depended on the species and the established spatial and temporal scales. Coefficients of variance were not effectively reduced by the doubling of the number of sampling units on the Puerto Rican mainland and Vieques Island. For example, the call-count surveys of the zenaida doves and scaly-naped pigeons on the Puerto Rican mainland had higher CVs in May 1991 (31 sampling units) than in May 1990 (15 sampling units). Because theoretically the standard error of a sample mean is $SD/(n)^{0.5}$, a decline in the variability of the counts with an increase in sample size was expected. Coefficients of variance of the counts increased or declined weakly with sample size, probably because the number of routes per life zone was not sufficient to capture the full extent of the spatial variability of the populations of pigeons and doves. A random sampling scheme is difficult in the field, hence a weak decline or increase in CVs of the counts can be expected until sampling is conducted at a sufficient number of routes per year per life zone to capture a significant proportion of the spatio-temporal distribution of the birds.

The data from the roadside counts were positively skewed and heterogeneous. Skewness and heterogeneity are characteristics of populations with patchy distributions in space and time because of habitat use and resource availability. As a result, at many 3-min stations per route the counts were zero or low and few counts were high (extreme; e.g., because of site tenacity of mated and unmated territorial males in patches of high-quality nesting habitat). When the counts of the 10 native species were pooled, the species-specific variability was underestimated because the number of 3-min stations with zero or low counts decreased and the data became more homogeneous (compare the shapes of the box plots of each species with those of the columbids in general). Hence, sample sizes (number of routes per life zone per year) were estimated on a species-specific basis. Coefficients of variance of relatively abundant and widely distributed species (habitat generalists such as zenaida doves and common ground-doves) were lower than CVs of relatively uncommon and local species (habitat specialists such as white-crowned pigeons and bridled quail-doves). For example, the roadside counts of the white-crowned pigeons were highly variable (CVs > 300%) because this species was usually detected in mangrove forests, but this habitat type encompassed only a fraction of the area surrounding the sampling routes on Vieques Island during May 1991 and 1992.

The necessary sample sizes for confidence limits of 10–50% for the mean number of calling zenaida doves and scaly-naped pigeons per km in the life zones during the reproductive peak were prohibitive. With mean CVs in the order of 81–

137% (May 1987–92) and annual sampling at 31 routes, the risk of not detecting significant between-year differences ($P \leq 0.05$) in the relative abundance of the two most important game species on the Puerto Rican mainland and Vieques Island was very high (Rivera-Milán et al. 1990; Rivera-Milán and Ramos, unpublished data). Moreover, after May 1989 sampling at each route was conducted only once per year; hence, some of the between-year variation of the roadside counts was probably attributable to extraneous sources (e.g., environmental factors such as rainfall and the seasonal abundance and availability of fruits of key tree species) and not necessarily to population changes (Rivera-Milán 1992). The examined surveys represent short-term efforts (2–6 years) of estimating population changes, and whether they reflect trends, seasonal variations, or regular (cycles) or irregular fluctuations in the life zones is difficult to determine. Nevertheless, the statistical analyses were done with good data (i.e., the counting procedures were standardized, there were no missing counts, and the same observers were involved from May to June 1987 to 1992). Unfortunately, the long-term attributes of the roadside counts will change and the analyses will become more complex as the number of routes for the yearly sampling increases or decreases, the observers change, and the years with missing data augment the risk of erroneous conclusions about the magnitude and direction of population changes in the life zones (Sauer and Droege 1990).

Seasonal (within-year) and annual (between-year) population changes can be examined with data from at least 3 counts/route (repeated sampling) during the reproductive peak and then with the mean trend as a measure of relative abundance of the most common and widely distributed species in the life zones (Winer 1971; Gurevitch and Chester 1986; Beal and Khamis 1990, 1991; Quinn and Keough 1991). For example, CVs of the call-count surveys of the zenaida doves in the dry zone in spring were 72.5% in 1987 and 24.4% in 1988; hence, when α equals 0.05, 53 sampling units were required for confidence limits of ±20% for the mean number of calling zenaida doves per km during spring of 1987 and 6 in spring of 1988. Repeated sampling (3 counts/route/season) reduced the underlying variability of the counts and facilitated the examination of seasonal and annual patterns of the distribution and relative abundance of the columbids in the three major life zones of the Puerto Rican mainland (Rivera-Milán 1990a, 1992).

Implications and Recommendations

The necessary within-year sample sizes per life zone for ±10–50% confidence limits for the mean number of aural and visual detections of the common and widely distributed species per km were prohibitive. The problem became more complex as new observers were needed to sample the routes in May–June 1991 and 1992. More personnel-days (cost) were required to sample at the new pool of routes in each life zone, yet the variability of the roadside counts remained relatively high. Therefore, the roadside counts were sensitive only to large between-year differences in the relative abundance of the most common and widely distributed species of pigeons and doves. A combination of counting techniques (e.g., roost, nest, and roadside counts) may be necessary to study population changes of uncommon and local species such as plain pigeons, white-crowned pigeons, and bridled quail-doves.

Guidelines for the Standardization of Roadside Counts

Counting standards should be as simple as possible to remain constant on a long-term basis. To facilitate the analysis of long-term population trends (≥10 years), I recommend the following set of standards: (1) conduct roadside counts between the second week of May and the second week of June to cover the reproductive peak of the columbids on the Puerto Rican mainland and on Vieques Island; (2) use observers with more than 3 years of experience to conduct as many roadside counts as possible and provide training to minimize the effects of new observers; (3) when possible, conduct the counts between 0600 and 0830 h to reduce time effects; (4) suspend the counts when it is raining or when wind speed exceeds 19 kph; (5) spend 3 min/sampling station; (6) discontinue the counts between 3-min stations to decrease the time spent per route; (7) keep the distance be-

tween 3-min stations at 1.6 km on the Puerto Rican mainland but at 0.8 km on Vieques Island (or on smaller islands such as Culebra and Mona); (8) record all observations of seen or heard pigeons and doves on standard data sheets, regardless of detection distance (unless well-trained observers are used [Rivera-Milán 1990a, unpublished data]); (9) have each count conducted by one (not driving) observer; (10) discontinue the counts of the number of calls given by the individuals of each species (the calling rate) at the stations; (11) record the time of day, weather conditions, and disturbance levels at each station; (12) explore the possibility of increasing the number of routes for annual sampling on the Puerto Rican mainland from 31 to 60 (10 in the dry zone, 30 in the moist zone, and 20 in the wet zone), and reexamine variances of call and sight counts on a route-by-route basis (Geissler and Noon 1981; Geissler 1984; James et al. 1990); and (13) conduct a minimum of 3 counts/route/year (April, May, and June) and use the average count per route to study changes in the relative abundance on a route-by-route basis (Gurevitch and Chester 1986). Because of the present levels of urbanization on the Puerto Rican mainland, the new routes will cover suburban landscapes that were excluded from the original sampling scheme.

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